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## Study on Key Certification Issues of Composite Airframe Structures for Commercial Transport Airplane

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### Abstract

In order to facilitate the type certification of COMAC C919 airplane and type validation of Boeing 787 Dreamliner and Bombardier CSeries airplane, this paper presents a study on key certification issues introduced by extensive use of composite on airframe structures for commercial transport airplane. Firstly, the background and application of six Special Conditions concerned are studied in detail. Secondly, such Special Conditions are classified into two applicability sorts, then the establishment and substantiation issues are discussed, some suggestions/ emphases are given. Finally, conclusions are provided with possible regulations evolvement, challenges faced and a solution proposed for the key certification issues.

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**Keywords:** Commercial Transport Airplane; Composite Airframe Structures; Special Condition; Airworthiness; Certification Standards;

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### 1. Introduction

Over the past two decades, military airplanes have driven the development of advanced composite materials, especially the Carbon Fiber Reinforced Plastic (CFRP) material, but today an increasing share of new commercial transport airplanes development is devoted to composite materials because of its high strength-density-ratio, excellent fatigue-resistance capability and corrosion-resistance capability compared

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with conventional metallic materials. Composite materials make up approximately 50% of the weight for the Boeing 787 Dreamliner, a sharp increase from the 12% for the Boeing 777 airplane, and 52% for Airbus 350XWB airplane as well as about 47% for Bombardier CSeries airplane. It has become a tendency for commercial transport airplanes to use this advanced composite materials on the primary airframe structures, i.e. on wing, empennage, fuel tank, aft pressure bulkhead and fuselage etc [1].

However, in addition to the benefits from the use of advanced composite materials, it will not only pose challenges for the airplane manufacturer whose design and processing experiences focused on metals, but also introduce certification issues to airworthiness agency because of the novel or unusual design features with composite airframe structures.

## **2. Concerns for extensive use of composite on airframe structures**

According to the Civil Aviation Rule of Civil Aviation Administration of China (CAAC), the type design of commercial transport airplane must be certified per CCAR-25, and a Special Condition should be prescribed by Aircraft Airworthiness Certification Department of CAAC to establish a level of safety equivalent to that established by the existing airworthiness standards [2], due to the following reasons for which the existing applicable airworthiness standards do not provide appropriate or adequate safety standards:

- Civil aviation product has novel or unusual design features,
- Intended use of civil aviation product is unconventional, or
- Experience from other similar product in service or product having similar design features has shown that unsafe conditions may develop.

The existing airworthiness standards and means of compliance have been originally built up from the experience gained with metallic structures. However, in the past, very few Special Conditions have been raised for composite structures on the basis that certification could be adequately addressed through tailored means of compliance as we can find in the Federal Aviation Administration (FAA) Advisory Circulars (AC) 20-107A. The situation is now moving when the wing, fuel tank and fuselage structures of large commercial transport airplanes are constructed with extensive advanced composite materials [3], such as Boeing 787 Dreamliner, Airbus 350XWB airplane and Bombardier CSeries airplane. This type of airplanes with novel or unusual design features compared with current fleet is needed reassessing to take composite special characteristics into account.

Then what Special Conditions should be established that can cover the type design with novel or unusual design features? What are the requirements of such Special Conditions that can control the unsafe factor? And what work should be accomplished to demonstrate the compliance with the requirements? These certification issues must be faced and solved will pose challenges for industry and agency.

The domestic Advanced Regional Jet (ARJ) 21-700 airplane with no more than 3% of composite on its structures will enter into service soon. The domestic COMAC C919 airplane is under research and development that the application of composite materials will adopt two steps strategy. The first step is to use approximately 15% of composite materials mainly on center tank, aft pressure bulkhead, empennage, and control surfaces etc, and the second step is to use nearly 23% of composite materials plus on composite wing and wing fuel tank [4]. In addition, Boeing 787 Dreamliner and Bombardier CSeries airplane are being conducted the concurrent type validation by CAAC with FAA and Transport Canada (TCCA) respectively. In order to further understand the impact introduced by extensive use of composite on airframe structures for the design and certification of COMAC C919 airplane or other future domestic airplanes, as well as facilitate type validation of Boeing 787 Dreamliner and Bombardier CSeries airplane, it is urgent to have a study on the certification issues introduced by extensive use of composite on airframe structures.

In this paper a large commercial transport airplane with at least all composite wing, fuel tank and fuselage structures is assumed. Based on Transport Category Airplanes Airworthiness Standard (CCAR-25/FAR-25/CS-25), and Special Conditions prescribed by FAA, European Aviation Safety Agency (EASA) and TCCA during type certification process, it is found that Special Conditions related to composite airframe structures may cover the following topics:

- Crashworthiness of composite fuselage
- Debris penetration of composite wing and fuel tank structures
- Composite wing and fuel tank structures post-crash fire survivability
- Composite fuselage in-flight flammability resistance
- Composite fuselage post-crash fire survivability
- Lightning protection of composite fuel tank structure

Considering the importance of Special Conditions, the study on key certification issues of composite airframe structures for commercial transport airplane will begin with detail introduction of six Special Conditions above and focus on related establishment and substantiation issues.

### *2.1. Crashworthiness of composite fuselage[5-6]*

The crashworthiness of airplane is dominated by the impact response characteristics of the fuselage. Generally, airworthiness regulations evolve based on either experience gained through incidents and accidents of existing airplane or in anticipation of safety issues raised by new designs. In the case of crashworthiness, airworthiness regulations have evolved as experience has been gained during actual airplane operations. For example, § 25.561 and § 25.562 are amended or newly added to reflect dynamic conditions observed from fleet experience and from the research of agency and industry. Fleet experience has not demonstrated a need to have an airplane level crashworthiness standard. As a result, the regulations reflect the capabilities of conventional aluminum airplane structures under survivable crash conditions. The level of safety established was acceptable for airplane constructed with conventional aluminum. With the advent of composite fuselage structures, it may no longer be sufficient to substantiate the same safety level of protection for the occupants as provided by similar metallic designs.

Structures fabricated from composite materials may behave differently than metallic structures due to differences in material ductility, stiffness, failure modes and energy absorption characteristics. Therefore, the impact response characteristics of composite fuselage structures must be evaluated to ensure that the survivable crashworthiness characteristics are not significantly different from those of a similarly sized airplane constructed with conventional aluminum. Impact loads and resultant structural deformation of the supporting fuselage and floor structures must be evaluated. There are no existing regulations that adequately address this potential difference in impact response characteristics for what are considered survivable crash conditions. Then Special Condition is necessary to ensure a level of safety equivalent to that provided by regulation Part 25.

Given the similarity of the fuselage impact response characteristics anticipated in the longitudinal direction when compared with the current fleet, it is acceptable that compliance will be based only on assessment of composite fuselage structures for the vertical direction crash conditions. Current regulations, including §25.561, §25.562, §25.721, §25.785, §25.789, §25.803, §25.809, §25.810, and §25.813, remain valid for this airplane but do not reflect the vertical descent velocities achieved during actual, in-service survivable crashes of transport airplanes.

The airplane performance with respect to the four capabilities below must be assessed over a range of airplane level vertical descent velocities from 0 to 30 ft/sec (assuming zero longitudinal velocity). Alternatively, a different airplane specific range of vertical descent velocities if substantiated on a rational basis is acceptable.

- Occupants must be protected during the impact event from release of items of mass (e.g., overhead bins).
- The emergency egress paths must remain following a survivable crash.
- The acceleration and loads experienced by occupants during a survivable crash must not exceed critical thresholds.
- A survivable volume of occupant space must be retained following the impact event.

Existing transport airplane requirements also require that fuel tank structural integrity be addressed during a survivable crash impact event as related to fire safety. As related to crashworthiness, composite fuel tank structures must not fail or deform to the extent that fire becomes a greater hazard than with metal structures.

Such Special Condition may be applicable to commercial transport airplanes with composite fuselage structures.

## *2.2. Debris penetration of composite wing and fuel tank structures[7-8]*

Accidents and incidents have resulted from uncontrolled fires caused by fuel leaks following penetration or rupture of the lower wing by fragments of tires or from uncontained engine failure. The Concorde disaster in 2000 is the most notable example. Impact to the wing surface by tire debris induced pressure waves within the fuel tank that resulted in fuel leakage and fire. The supersonic airplane's wing skin is made of aluminum having a thickness less than that of a conventional subsonic airplane. Agencies subsequently required modifications to the Concorde to improve impact resistance of the lower wing, or means to retain fuel if the primary fuel retention means is damaged. In another incident, a Boeing 747 airplane's tire burst during an aborted takeoff. That tire debris penetrated a fuel tanks access cover causing substantial fuel leakage. Passengers evacuated down the emergency chutes into pools of fuel that fortunately had not ignited.

These accidents highlight deficiencies in the existing regulations part 25 pertaining to fuel retention following impact of the fuel tanks by fragments or debris. After a 1985 Boeing 737 airplane accident in England, in which a fuel tank access panel was penetrated by engine debris, §25.963(e) was amended to require fuel tank access covers that are resistant to tire fragments, low energy engine debris or other likely debris, unless the covers are located in an area where service experience or analysis indicates a strike in not likely (engine debris is also addressed in §25.903(d) which requires minimizing the hazards to the airplane in the event of an engine rotor failure). § 25.963(e) only addressed the fuel tank access covers since service experience at that time showed that the lower wing skin of a conventional subsonic airplane provided adequate inherent capability to resist high speed objects such as tire and engine debris. No specific requirements were established for the contiguous wing areas into which the access covers are installed. FAA AC 25.963-1 specifically states, "The access covers, however, need not be more impact resistant than the contiguous tank structure," highlighting the assumption that the wing met some higher standard.

The capability of conventional aluminum wing skins to resist penetration or rupture when impacted by tire debris is understood from extensive experience, but the ability of composite materials construction to resist these hazards has not been established. The above threat is similarly applicable to the remainder of the composite wing and fuel tank, there are no current requirements specifically addressing this hazard for all the exposed wing surfaces. Then the following Special Condition is necessary to ensure the level of safety is not decreased relative to existing experience with metallic structures:

- Impacts by tire debris to any fuel tank or fuel system component located within  $\pm 30$  degrees of the wheel rotational planes may not result in penetration or otherwise induce fuel tank deformation, rupture (for example, through propagation of pressure waves), or cracking sufficient to allow leakage

of hazardous quantities of fuel. Any fuel leak resulting from debris impact to a fuel tank surface which under maximum fuel head conditions is a running leak, dripping leak, or one that results in a wetted area that exceeds 6 inches wide (determined 15 minutes after wiping dry the area of damage) is hazardous.

- Compliance with paragraph (a) must be shown by analysis or tests assuming tire debris consists of 1 percent of the tire mass propelled at a tangential speed that could be attained by a tire tread at the airplane flight manual airplane rotational speed (VR at maximum gross weight) and be distributed over an area equal to 1½ percent of the total tire tread area.
- Leakage of fuel from any portion of a fuel tank located within the tire debris impact area in quantities exceeding those defined in (a), may not result in hazardous quantities of fuel entering any engine inlet, APU inlet, or cabin air inlet of the airplane. This must be shown by test or analysis, or a combination of both, for any approved engine forward or reverse thrust condition.

Such Special Condition may be applicable to commercial transport airplanes with composite wing and fuel tank structures.

### 2.3. Composite wing and fuel tank structures post-crash fire survivability[5,9-10]

FAA AC 20-107B *Composite Aircraft Structure*, under the topic of fire protection, flammability and thermal issues, states: “Requirements for flammability and fire protection of aircraft structure attempt to minimize the hazard to the occupants in the event that flammable materials, fluids or vapors ignite. A composite design, including repair and alterations, should not decrease this existing level of safety relative to metallic structures.” Pertinent to the wing and fuel tank structures, post-crash fire occupant survivability is dependent upon the time available for occupant evacuation prior to fuel tank rupture or structural failure. Structural failure can be a result of degradation in load-carrying capability in the upper or lower wing surface caused by a fuel-fed ground fire, and can also be a result of over-pressurization caused by ignition of fuel vapors internal to the fuel tank.

Large transport airplanes in operation to date have been designed with conventional aluminum materials. The inherent capability of aluminum to resist fire has been considered in development of the existing regulations. The definition of fire resistance is defined for testing of materials in FAA AC 20-135 as the capability to withstand a 2000°F flame for 5 minutes. The existing regulation has been historically promulgated with the assumption that the material of construction for wing and fuel tank would be aluminum. As a typical case, §25.963 was promulgated as a result of a large fuel-fed fire following the failures of fuel tank access doors caused by uncontained engine failures based on the recognition that existing aluminum wing and fuel tank structures provided an acceptable level of safety.

For under-wing mounted engines, the wing tanks and center tanks are located in proximity to the passengers and near the engines. Past experience indicates post crash survivability is greatly influenced by the size and intensity of any fire that occurs. The ability of aluminum wing surfaces wetted by fuel on their interior surface to withstand post-crash fire conditions has been demonstrated by tests. Results of these tests have verified adequate dissipation of heat across wetted aluminum fuel tank surfaces so that localized hot spots do not occur, thus minimizing the threat of explosion. This inherent capability of aluminum to dissipate heat also allows the wing lower surface to retain its load carrying characteristics during a fuel-fed ground fire and significantly delay wing collapse or burn-through for a time interval that usually exceeds evacuation times. In addition, as an aluminum fuel tank is heated with significant quantities of fuel inside, fuel vapor accumulates in the ullage space, exceeding the upper flammability limit relatively quickly and thus reducing the threat of a fuel tank explosion prior to fuel tank burn-through. Service history of conventional aluminum airplanes has shown that fuel tank explosions caused by ground fires have been rare on current fleets.

The extensive use of composite materials in the design of wing and fuel tank structures is considered a major change from traditional methods of construction. For the transport airplane with composite wing and fuel tank structures, it may be exposed to the direct effects of post-crash ground or under-wing fuel-fed fires and may or may not have equivalent capability of aluminum. Existing regulations do not provide objective performance requirements for wing and fuel tank structures with respect to post-crash fire safety. Then Special Condition is necessary to show that the use of composite for wing and fuel tank structures does not decrease the level of safety relative to metallic structures. This could be achieved by showing that from a fire withstanding capability, the composite wing and fuel tank structures are at least equivalent to a similar wing constructed with aluminum, or the design of wing and fuel tank, including all access covers, can endure an external fuel fed fire for at least five minutes. This shall be demonstrated for minimum fuel loads (not less than reserve fuel level) and maximum fuel loads (maximum range fuel quantities), and/or other identified critical fuel loads. Considerations shall include fuel tank flammability, burn-through resistance, wing structural strength retention properties, and auto-ignition threats.

Such Special Condition may applicable to commercial transport airplane with composite wing and fuel tank structures.

#### *2.4. Composite fuselage in-flight flammability resistance[5,11-15]*

In the past, fatal in-flight fires have originated in inaccessible areas of the airplane where the thermal/acoustic insulation materials located adjacent to the aluminum airplane skin has been the path for flame propagation and fire growth. Although the insulation materials were required to comply with the basic "Bunsen burner" requirements of §25.853(a) and §25.855(d), these incidents or accidents revealed unexpected flame spread along the insulation film covering material of the thermal/acoustic insulation. In all cases, the ignition source was relatively modest and, in most cases, was electrical in origin (i.e. an electrical short circuit). After the MD-11 airplane in-flight fire accident in 1998 that the fatal fire appeared to involve the insulation blankets of the area above the cockpit and forward cabin ceiling, flammability test method (radiant panel test) and related test criteria were specifically established in order to improve the in-flight fire ignition/flame propagation of thermal/acoustic insulation materials, and finally §25.856(a) was developed to reduce the incidence and severity of cabin fires, particularly those ignited in inaccessible areas where thermal acoustic insulation materials are typically installed.

The performance of airplane fuselage constructed with conventional aluminum in an inaccessible in-flight fire scenario is understood based on service history and extensive large-scale fire testing. The fuselage itself does not contribute to in-flight fire propagation. However, for a composite fuselage, the conclusion based on the premises of an aluminum structures may not be applicable anymore.

Therefore, to keep consistency with the general safety objective, the composite fuselage must provide protection against an in-flight fire propagating along the surface of the fuselage. While, eliminating the propagation of fire along the composite fuselage is the primary concern and it is unlikely that other parameters which may influence in-flight fire safety, such as smoke obscuration or toxic gas emission, will be an issue. These factors are typically the results of a propagating fire; however, it is necessary to include a requirement to conduct an evaluation of the cabin environment to assess any potential hazards that may affect fire safety resulting from the in-flight fire.

Then Special Condition is necessary to demonstrate the level of safety not decreased compared to Aluminum fuselage. It must be shown that the in-flight fire safety of the composite fuselage can resistant to flame propagation and if the products of combustion are observed beyond the test heat source, these must be evaluated for acceptability.

Such Special Condition may applicable to commercial transport airplane with composite fuselage.



### *2.5. Composite fuselage post-crash fire survivability[5,16-17]*

A number of large transport airplane accidents have occurred in which spilled jet fuel ignited and fires penetrated the fuselage, ignited the interior, and caused numerous fatalities. In recent years, an effort to improve occupant survivability by conducting research on the effects of flame penetration into the cabin and focusing on gaining a better understanding of the mechanism and time frame for fuselage burnthrough was begun and several large-scale fire tests on aluminum skin fuselage panels with representative interior components such as sidewall and ceiling panels, carpets, airplane systems, floor panels, and insulation were conducted. Survivability parameters such as skin temperature, temperature behind the insulation materials, cabin temperature, smoke emission, and the quantities of toxic gases produced were measured and evaluated along with the time for fire penetration. Results showed that smoke and toxic gas emissions did not need to be separately addressed because they did not become an issue until after penetration of the fire into the cabin. Finally, §25.856(b) was developed to require that thermal/acoustic insulation materials installed in the lower half of the fuselage must meet the flame penetration resistance requirements of part VII of Appendix F to part 25.

Based on service experience and tests, traditional aluminum fuselage materials and insulation systems have not detrimentally affected the survivability. However, for composite fuselage, the conclusions based on the premises of an aluminum fuselage may not be applicable. Because the possibility of smoke or toxic gas emissions could have a significant impact on survivability, it is necessary to assess the cabin survivability during a post-crash fire to ensure that no unsafe conditions introduced. The impact on the rescue effort should also be assessed. Surface temperature, structural integrity and combustion gaseous products are among potential concerns.

Then Special Condition is therefore to be defined to demonstrate the level of safety relative to existing experience with metallic structures is not reduced. It must be demonstrated that negligible amounts of smoke, toxic gases and released fibers are produced by the composite material during a post crash fire, before the fire penetrates the cabin, and that no other aspects of post-crash survivability have been compromised, in comparison to a conventional aluminum fuselage, before the fire penetrates the cabin. For example, the effects of fire on the composite fuselage could result in delays in the action of rescue crews, or increased danger to them.

Such Special Condition may applicable to commercial transport airplane with composite fuselage.

### *2.6. Lightning protection of composite fuel tank structure[5,18]*

This Special Condition is prescribed by FAA for Boeing 787 Dreamliner with composite fuel tank structure.

Because the carbon fiber reinforced plastic (CFRP) materials are not as thermally or electrically conductive as conventional aluminum structures. The Boeing 787 airplane fuel tank design feature combined with the difficulty in detecting failures of hidden structural elements in general makes compliance with §25.981(a)(3) uniquely challenging and impractical for certain structural bonding aspects of lightning protection.

The Boeing 787 airplane will also incorporate a fuel tank Nitrogen Generation System (NGS) which, when operating as intended, minimizes the flammability exposure within the fuel tanks. This novel design feature not only provides for a unique means of complying with §25.981(c), but represents a compensating feature such that the level of ignition prevention required by §25.981(a) (3) may be unnecessary to achieve the intended level of safety.

Given these novel compliance challenges and design features, FAA has determined that it is neither practical nor necessary to apply the provisions of §25.981(a)(3) as written to specific fuel tank structural

lightning protection features of the Boeing 787 airplane. Furthermore, without the §25.981(a) (3) provisions, the remaining applicable regulations within the Boeing 787 airplane type certification basis are inadequate. Hence, FAA establishes such Special Condition to be applied in lieu of §25.981(a) (3) to fuel tank lightning protection features that are integral to the basic airframe structures or permanent systems supporting structures.

### 3. Analysis of key certification issues

Certification of composite airframe structures for commercial transport airplane is one of the main concerns of applicant and Type Certification Team, and the Special Conditions introduced by composite airframe structures are focus of both sides. Then key certification issues of composite airframe structures urgent to be solved include at least the following aspects.

#### 3.1. Establishment issue of Special Condition

Depending on the applicability of each Special Condition mentioned above, they can be classified into two applicability sorts:

Table 1: Applicability sorts of Special Conditions

Applicability sorts	Topics
Composite fuselage	Crashworthiness of composite fuselage
	Composite fuselage in-flight flammability resistance
	Composite fuselage post-crash fire survivability
Composite wing and fuel tank	Debris penetration of composite wing and fuel tank structures
	Composite wing and fuel tank structures post-crash fire survivability
	Lightning protection of composite fuel tank structure

Even though the establishment principle is obtained, during type certification process, Special Conditions for same airplane prescribed by different agencies may be different, i.e. for Hawker 4000 airplane with composite fuselage, EASA establishes Special Conditions covering flammability and resistance to fire (in-flight and post-crash), while, FAA does not [19, 20].

After the topics of applicable Special Conditions are determined, the next step is to prescribe its detail requirement. It is important to understand that the airworthiness standards require the applicant to achieve is minimum standards, and for agency to require something other than what is outlines in the regulations is not only inappropriate, it is illegal [21]. Then the difficult is that, if the requirement is not sufficient, novel or unique design feature cannot be covered, the level of safety may decrease, thus the safety of airplane and public interest are affected. On the other side, applicant and agency will face more challenges, increase costs and violate the objective of promoting the development of the civil aviation.

In fact, the detail requirement of Special Condition may vary as the difference of airplanes and agencies. For example, FAA and aircraft manufacturers have collected a significant amount of experimental data as well as data from crashes of transport airplanes, especially the vertical impact drop test of Boeing 737-200 fuselage section at FAA William J. Hughes Technical Center that the airplane was dropped from a height of 14 feet, generating a vertical impact velocity of 30ft/sec. They consider that the data demonstrate a high occupant survival rate at vertical descent velocities up to 30 ft/sec on Boeing 737 airplane [22]. Based on this information, FAA finds it appropriate and necessary for an assessment of the



composite airframe to span a range of airplane vertical descent velocities (up to 30 ft/sec, or that appropriate for a comparable sized airplane). While, Airbus studies have indicated a vertical descent velocities up to 22ft/sec represents the point at which a conventional Airbus 340 airplane fuselage becomes severely disrupted. This is shown by an analytical model which demonstrates failure of the floor beams and significant lower shell failure at this speed. The value of 22 ft/sec can be regarded as an acceptable vertical descent velocity for demonstration of crashworthiness fuselage [23]. The main reason caused this difference is that the establishment of such Special Condition is to compare with airplane fabricated from metallic materials and there is no any detail level of safety for metallic airplane.

Thus CAAC and applicant should make further efforts on the following aspects:

- Well understanding of design philosophy and technologies of commercial transport airplane, which is a foundation of identifying the novel or unusual design features.
- Well mastering of backgrounds and basic assumptions of related regulation provisions, which is a starting of establishing a level of safety equivalent to that established by the existing airworthiness standard.
- Studying on existing agency position and certification experiences of similar or comparable airplane.

### 3.2. Substantiation issue of Special condition

It may be more complex on substantiation of Special Condition than its establishment.

According to *Aircraft type certification procedures* (AP-21-AA-2011-03-R4), 10 typical certification Means of Compliance (abbr. for MC) are defined, including statement of compliance (MC0), description (MC1), calculation / analysis (MC2), safety assessment (MC3), laboratory test (MC4), ground tests on aircraft (MC5), flight tests (MC6), inspection by the agency (MC7), simulator testing (MC8), equipment qualification (MC9). One or more MCs can be selected for showing compliance with specific regulation provision or Special Condition. In general, calculation/ analysis (MC2) and laboratory test (MC4) are commonly used to demonstrate the compliance with six Special Conditions discussed above. Thus CAAC and applicant should concern and emphasize on the following aspects:

- If MC4 alone is selected to show compliance, it is difficult to conduct detail laboratory test, including the determination of test product, test equipment, test steps and pass/fail criteria etc. This may involve large quantity of costs, human resources or delay project progress. However, MC4 is a basis of analysis, and an effective method to demonstrate compliance.
- If MC2 alone is selected to show compliance, it must be shown that this engineering analysis method is reliable or supported by test evidence. This may involve the degree of correlation between analysis and test and practices to improve the accuracy and predictability of analysis. Although FAA AC 20-146, *Methodology for Dynamic Seat Certification by Analysis for Use in Parts 23, 25, 27, and 29 Airplanes and Rotorcraft* providing available guidance on validating analytical tool is a methodology for dynamic seat, much of the information is applicable to any computer modeling analysis used to determine dynamic structural behavior.
- Usually, MC2 and MC4 are used together to show compliance. For example to demonstrate the compliance with composite fuselage crashworthiness of Boeing 787 Dreamliner, it can be found from the website that Boeing has conducted a vertical drop test of a 10 ft long fuselage section from about 15 ft to validate the analytical tool and will use computational analysis to simulate various crash scenarios instead of further physical tests.

## 4. Conclusions

As the regulations evolvement, these Special Conditions may be incorporated into regulation, if one day they have a generic characteristic, i.e. they are applicable to all airplanes incorporating composite technology. For example, a Special Condition covering HIRF has been incorporated into 14CFR Part 25 during Amendment 25-122 and EASA is proposing to incorporate lots of generic Special Conditions into EASA Certification Specifications (CS) 25 thought NPA 2011-09. Before these Special Conditions incorporating into regulation, they can be good practices and references for both CAAC and its applicants on those projects that the composite materials are used on primary airframe structures of transport category airplanes.

Though great successful experiences gained from composite application on domestic military and civil airplanes, and expeditious progress and achievement of CAAC certification capability on composite, there is still long distance between us and FAA and EASA about the capability of composite design and certification, especially about the capability of composite on primary airframe structures for large commercial transport airplane. Current domestic Advanced Regional Jet (ARJ) 21-700 airplane represents the high-level of design and manufacture of composite materials, which the composite application is much less than that of Airbus 350XWB airplane and Boeing 787 Dreamliner, This means the applicants should put more efforts on composite application, and CAAC will face the challenges of shortage of certification cases and explanatory materials.

On the other side, FAA, EASA and its applicants have conducted quantity of researches on composite application, including the Building Block Approach for crashworthiness of composite structures [24].

CAAC and its applicants should conduct further studies as early as possible and strengthen the global communication and cooperation. The solution of key certification issues of composite airframe structures for commercial transport airplane, in a word, must be depending upon the Confidence, Communication, Coordination and Cooperation among agency, applicants, and universities as well as research institutes.

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